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ABSTRACT

Reported are results of a study that examined the relationships between university students' entry characteristics and achievement in biology. Variables judged most likely to be predictors of achievement were: (1) scholastic aptitude (quantitative and verbal): (2) level of cognitive development: (3) locus of control: (4) grade point average: (5) age: and (6) gender. Data on achievement variables were collected with the administration of four multiple-choice objective referenced tests. Data from over 1000 students in introductory biology at the University of Georgia were examined by using regression analysis and general linear model procedures with SAS computer programs. Results included the finding that on all the biology achievement measures, the SAT (quantitative) score was the single best predictor of achievement, while the second best predictor was level of cognitive development. Implications are discussed regarding the improvement of postsecondary science instruction. (CS)

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PREDICTING SCIENCE ACHIEVEMENT OF UNIVERSITY STUDENTS ON THE BASIS OF SELECTED ENTRY CHARACTERISTICS

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SE 035 231

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INTRODUCTION

Purpose

Science achievement varies greatly across university students. This variation is contributed to and influenced by many variables. Some of these variables can be manipulated and are more or less under the control of the instructor. Others are personalogical variables which are not manipulable but need to be identified and recognized for their influence on achievement. Benjamin Bloom (1976) recently hypothesized that more learning is influenced by a student's entry characteristics than by variations in teaching. The purpose of this study was to examine the relationships between university students' entry characteristics and achievement in biological science. The variables which were judged most likely to be predictors of achievement because of the nature of the subject matter or instructional conditions were: scholastic aptitude (quantitative and verbal); level of cognitive development; locus of control; grade point average; age; and, gender.

Rationale

Scholastic aptitude as measured by the SAT was selected because of its use as a university entrance examination. However, its predictive power is severely limited by a restricted range. Nevertheless, the nature of the concepts and problems being studied and the nature of the pedagogy (much reading and lecture) suggests that variations in scholastic ability may lead to or predict variations in science achievement.

Cognitive development level was selected because many science concepts are abstract or are studied through abstract models. Students who possess more formal levels of abstract reasoning ability should perform better than students with less of this ability.

Grade point average (GPA) was needed to examine the degree of relationship that exists between success in biology and general success in other university courses. Any relationship would be strictly correlational (as opposed to causal) but may point the way to identifying the causal variables.

Student locus of control (LOC) was selected as a predictor variable because of the high level of freedom and independence associated with the task of studying by university students. This freedom should favor students with an internal locus of control. The external student may not recognize regular and systematic study as a variable responsible for increased achievement.

Age of student may be related to science achievement for two reasons: 1) the older student may be more mature and possibly more goal and achievement oriented; and, 2) it is the norm that science courses (in this case biology) are taken during the freshman year. It is possible that students who enroll in these courses at a later time will have adjusted to the rigors of university study and, therefore, be more successful in relation to achievement.

Gender has been regularly documented as a predictor of success in science courses. Most of the evidence to support this conclusion has been gathered at the pre-college level. It was of interest to this study to examine the degree of continuation of this effect.

PROCEDURES

Selection of Subjects

The subjects in this study were university students enrolled in an introductory biology course at the University of Georgia. More than 1200 students registered for the course; however, only those completing at least three of five, or two of four, achievement tests, and those for which data on the independent variables could be obtained were included in analyses.

Data Collection

Data on the entry variables were collected through standardized tests or from student files. Locus of control was assessed by the Intellectual Achievement Responsibility Questionnaire (IAR) (Crandall, Katkovsky and Crandall, 1965) in the Summer 1979 study, and by Levenson's multidimensional scales (I, P, C) (Levenson, 1972, 1973) in the Summer 1980 study. The Test of Logical Thinking (TOLT) (Tobin and Capie, 1980) was used to measure the cognitive development level of the subjects. Age, SAT scores, gender and GPA were available in conventional university computer stored records which were accessible by a student code number while maintaining the anonymity of the student.

Data on all achievement variables were collected with multiple-choice objective referenced tests. All items had been piloted previously. Item and test analyses were used to establish reliabilities (see Table 1) and objective-item matching by judges was used to insure content validity.

Instruction was delivered by the same instructor for both Winter and Summer 1980 quarters, while a second instructor provided instruction for Summer 1979, and Spring 1980. Table 1 provides a summary of the main topics

covered by each test for the four quarters. One should note that due to differences in teacher preference and length of time in the quarter, there are differences in tests from quarter to quarter. Although biology concepts were introduced in different sequences throughout the study, the items used to assess each objective remained essentially identical from quarter to quarter.

Data Analysis

Data were examined using the Statistical Analysis System (SAS) computer package. Regression analyses and general linear models were used to assess the relationship between student achievement and the independent variables scholastic aptitude (SATQ and SATV), locus of control (LOC+, LOC-, and LOCUS), cognitive development (TOLT), gender (SEX), collegiate grade point average (GPA), and age (AGE) in years. Note that data were not collected for all independent variables each quarter.

RESULTS

Table 2 is a summary of the results from regression analyses in which the "best" one, two, three, four, and five variable models were sought. Two criteria were simultaneously applied to determine which set of independent variables comprised the most parsimonious model for predicting biology achievement. Selecting models which maximize the most commonly used criterion, R^2_p, the coefficient of multiple determination [1 - (SSerror/SStotal)], and

minimize the C_p criterion[1] provides a means for evaluating which models predict the greatest amount of variation in achievement, and yet have the least error component.

Educational researchers should consider not only the amount of variation that can be predicted in a variable, but also the loss of sensitivity and added expense which occur when non-significant predictors are included in research studies. One can see in Table 2 that R^2 increases in every model as additional variables are added to the predictive models. Also note that in most of the models the additional predicted variation appears to be increasing C_p and the error in measurement. For the majority of models a three variable predictive model is the most parsimonious. Subsequent analyses of the three variable models showed that only two of the three variables consistently predicted statistically significant variation in achievement.

Table 3 is a summary of the relationship between achievement and each independent variable used in the study (R^2 values given). The best two variable models and their R^2 values are given as well (note that each variable in the model is underlined).

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[1] See discussions in Younger, Neter and Wasserman, and Daniel and Wood for examples using the criteria. C_p, Mallows C_p, is a function of the total squared error for a subset of independent variables SSEp, the mean square error for the full model, MSE the same size, and the number of independent variables in the subset P.

$$C_p = \left[\left(\frac{SSE_p}{MSE_{(X_1, \ldots, X_{p-1})}}\right) - (n-2p)\right]$$

Consistently across each quarter Winter through Summer 1980, demonstrated scholastic ability (GPA) appears as the most significant predictor of biology achievement. The results from Summer 1979, show that SATQ replaces GPA as the most significant predictor. These two variables combine to produce the "best" predictive model in 14 of the 18 models.

The average R^2 for each quarter, using a two variable model ranged from 0.30 to 0.42, where average R^2 was: 0.42 Summer 1979, 0.34 Winter 1980, 0.30 Spring 1980, and 0.35 Summer 1980.

CONCLUSIONS

Results of regression analyses in this study seem to support Bloom's (1976) hypothesis. That is, both cognitive and affective characteristics of students significantly influence their learning and subsequent achievement in college biology. However, the results of this study do not permit statements to be made about the relationship between achievement and variations in teaching strategies. In two investigations reported previously (Yeany, Helseth, and Barstow, 1980; and Yeany, Helseth and Adams, 1981) using the same groups of students from Summer 1979 and 1980, found that variations in teaching strategy (interactive video tapes and diagnostic remedial and instruction) can influence college biology achievement; but not as much as student entry characteristics.

It is not surprising that GPA emerges as the most significant predictor of college biology achievement. The conspicuous absence of other personalogical variables, cognitive development, locus of control, and achievement motivation, in the "best" predictive models was surprising to these investigators.

If we indeed have reliable and valid measures of student entry characteristics and college biology achievement, then one is inclined to conclude that variations in college biology achievement are primarily a function of students' quantitative thinking abilities and previously exhibited academic performance; though not significantly influenced by variations in locus of control and achievement motivation.

It might be argued that GPA is a product of various abilities, attitudes, experiences, etc., and should not be considered as a variable within itself. If GPA is a product of abilities such as quantitative and qualitative scholastic aptitude, then one would expect variation in achievement predicted by GPA to be predicted by SATQ and SATV as well. Results from regression models in this study do not support such a view. When GPA was not included in regression models, R^2 values for the models decreased substantially. The variation in achievement predicted by GPA in all but a few models appears to be unique variation. GPA might, therefore, be considered as a "synergistic" variable, where the whole is more or different than the sum of the parts.

The differences noted in SATQ and GPA for Summer 1979 can be explained by the presence of a group of students having a probationary academic status. These students were enrolled in the university even though their academic aptitude scores were below those required in admission standards. As a consequence this group differentially influenced the results of regression analyses. Since they had low SATQ and SATV scores and no GPA, their SAT scores increased the range for the sample, which increased the power of regression analysis to predict achievement. The absence of a GPA on the other hand automatically eliminated these students from the model building analyses.

The fact that student entry characteristics are consistent and strong predictors of achievement is not surprising but should be noted by instructors and curriculum developers. Where possible, efforts need to be applied to reduce differences in learning due to differences in student characteristics which can be overcome with appropriate instruction. Science classes should not offer simple processes where the "cream floats" but rather should provide opportunities for many types of students to realize their potential. Variation in achievement will still exist but probably at some reduced level.

Table 1

SUMMARY OF DATA AND RELIABILITIES ON ALL ACHIEVEMENT EXAMS

Quarter	Test	Cronbach	S_{em}	$\overline{X}$	Major Concepts
Summer 1979	1	.78	2.75	23.32	Cell division & reproduction
	2	.84	2.71	25.00	Protein synthesis & chemistry
	3	.76	1.95	12.26	Classical genetics quiz
	4	.71	2.78	23.96	Classical & modern genetics
Winter 1980	1	.84	2.28	30.13	Cell structure & chemistry
	2	.81	2.45	26.18	Cell division & reproduction
	3	.73	2.61	27.11	Protein synthesis
	4	.86	2.33	29.87	Classical & modern genetics
	5	.75	2.31	30.39	Evolution
Spring 1980	1	.83	2.65	25.06	Cell division & reproduction
	2	.80	2.73	23.78	Chemistry, classical genetics
	3	.65	1.79	14.09	Classical genetics quiz
	4	.85	2.52	27.87	Cell structure, modern genetics
	5	.75	2.47	29.85	Evolution
Summer 1980	1	.88	2.54	26.75	Chemistry, cell structure & division
	2	.82	2.54	26.29	Animal development & reproduction, protein synthesis
	3	.78	2.66	22.65	Classical & modern genetics

Table 2

RESULTS OF MULTIPLE REGRESSION ANALYSIS SHOWING THE SINGLE AND BEST MULTIPLE-VARIABLE MODELS WHICH PREDICTED ACHIEVEMENT

	R^2	C_p	Variable	R^2	C_p	Variables in model
SUMMER 1979						
TEST 1	0.018	51.53	LOC−			
	0.025	50.85	LOC+	0.513	6.38	SATQ GPA
	0.130	40.82	GPA	0.550	4.84	SATQ GPA LOC+
	0.154	38.59	SATV	0.574	4.54	SATQ GPA TOLT LOC+
	0.386	16.40	TOLT	0.589	5.07	SATQ SATV GPA TOLT LOC+
	0.463	9.13	SATQ			
TEST 2	0.00	18.68	LOC+			
	0.00	18.61	LOC−	0.359	−0.34	SATQ GPA
	0.022	17.38	SATV	0.367	1.16	SATQ GPA TOLT
	0.073	14.39	GPA	0.369	3.05	SATQ GPA TOLT SATV
	0.138	10.61	TOLT	0.369	5.00	SATQ GPA TOLT SATV LOC−
	0.330	−.69	SATQ			
TEST 3	0.007	39.79	LOC−			
	0.011	39.45	LOC+	0.515	1.47	SATQ GPA
	0.072	34.62	SATV	0.531	2.19	SATQ GPA TOLT
	0.081	33.93	GPA	0.539	3.50	SATQ GPA TOLT LOC+
	0.394	9.04	TOLT	0.545	5.09	SATQ GPA TOLT LOC+ LOC−
	0.477	2.50	SATQ			
TEST 4	0.003	20.25	LOC−			
	0.042	17.94	LOC+	0.295	4.61	SATQ GPA
	0.074	15.97	SATV	0.334	4.26	SATQ LOC+ LOC−
	0.096	14.66	GPA	0.381	3.44	SATQ LOC+ LOC− GPA
	0.099	14.47	TOLT	0.386	5.15	SATQ LOC+ LOC− GPA TOLT
	0.236	6.20	SATQ			
WINTER 1980						
	0.001	234.76	AGE			
	0.004	232.89	SEX	0.333	3.12	SATQ GPA
TEST 1	0.048	201.65	TOLT	0.336	2.96	SATQ GPA SEX
	0.052	198.80	SATV	0.337	3.78	SATQ GPA SEX AGE
	0.142	135.44	SATQ			
	0.300	23.97	GPA			
	0.007	317.27	SEX			
	0.008	316.29	AGE	0.392	13.42	SATQ GPA
TEST 2	0.061	274.25	TOLT	0.401	8.31	SATQ GPA AGE
	0.071	265.90	SATV	0.406	5.99	SATQ GPA AGE SEX
	0.156	199.50	SATQ			
	0.361	35.81	GPA			
	0.000	249.96	AGE			
	0.002	248.33	SEX	0.351	0.26	SATQ GPA
TEST 3	0.049	215.01	SATV	0.352	1.26	SATQ GPA TOLT
	0.079	193.38	TOLT	0.353	3.01	SATQ GPA TOLT SEX
	0.179	121.13	SATQ			
	0.294	39.69	GPA			

Table 2 (continued)

	R^2	C_p	Variable	R^2	C_p	Variables in model
WINTER 1980 continued						
	0.004	258.94	SEX			
	0.004	258.55	AGE			
TEST 4	0.028	241.22	SATV	0.356	5.84	SATQ GPA
	0.054	222.55	TOLT	0.361	4.32	SATQ GPA SEX
	0.119	174.82	SATQ	0.364	4.06	SATQ GPA SEX AGE
	0.337	17.69	GPA			
	0.000	160.35	SEX			
	0.001	159.96	AGE			
	0.038	136.46	TOLT	0.258	0.77	GPA SATV
TEST 5	0.057	124.67	SATV	0.260	1.60	GPA SATV SATQ
	0.069	116.90	SATQ	0.261	3.33	GPA SATV SATQ TOLT
	0.246	6.73	GPA			
SPRING 1980						
	0.008	89.35	AGE			
	0.011	88.32	SATV			
TEST 1	0.013	87.82	SEX	0.286	5.39	GPA SATQ
	0.064	71.87	TOLT	0.302	2.59	GPA SATQ SATV
	0.188	43.85	SATQ	0.305	3.60	GPA SATQ SATV SEX
	0.224	22.49	GPA			
	0.005	92.19	AGE			
	0.024	86.29	SEX			
TEST 2	0.045	79.53	SATV	0.286	5.07	GPA SATQ
	0.093	64.39	TOLT	0.299	2.67	GPA SATQ SEX
	0.158	44.64	SATQ	0.305	3.04	GPA SATQ SEX TOLT
	0.222	23.21	GPA			
	0.002	93.41	SEX			
	0.012	90.37	AGE			
TEST 3	0.049	78.78	SATV	0.306	2.02	GPA SATQ
	0.080	69.30	TOLT	0.313	1.84	GPA SATQ TOLT
	0.124	55.94	SATQ	0.315	3.26	GPA SATQ TOLT AGE
	0.272	10.39	GPA			
	0.000	90.39	SATV			
	0.003	89.66	AGE			
TEST 4	0.011	87.19	SEX	0.279	9.78	GPA SATV
	0.029	81.90	TOLT	0.303	4.95	GPA SATV SATQ
	0.056	73.76	SATQ	0.311	4.56	GPA SATV SATQ SEX
	0.257	14.45	GPA			
	0.000	100.00	AGE			
	0.029	91.04	SEX			
TEST 5	0.052	84.15	TOLT	0.312	6.38	GPA SATQ
	0.062	81.39	SATV	0.334	1.56	GPA SATQ SEX
	0.146	55.66	SATQ	0.339	3.24	GPA SATQ SEX SATV
	0.279	15.52	GPA			

Table 2 (continued)

	R^2	C_p	Variable	R^2	C_p	Variables in model
SUMMER 1980						
	0.000	49.12	AGE			
	0.001	48.94	LOCUS			
TEST 1	0.007	48.21	SEX	0.442	-1.28	GPA SATQ
	0.012	47.58	ACHMOT	0.429	-0.17	GPA SATQ ACHMOT
	0.017	46.99	SATV	0.432	1.49	GPA SATQ ACHMOT SATV
	0.094	37.44	TOLT			
	0.146	31.01	SATQ			
	0.415	-2.38	GPA			
	0.000	49.55	ACHMOT			
	0.002	49.33	LOCUS			
TEST 2	0.003	49.16	AGE	0.394	-0.28	GPA SEX
	0.008	48.56	SATV	0.404	0.46	GPA SATQ SATV
	0.019	47.05	SEX	0.409	1.78	GPA SATQ SATV SEX
	0.104	35.90	TOLT			
	0.122	33.48	SATQ			
	0.381	-0.61	GPA			
	0.000	39.28	LOCUS			
	0.002	39.12	ACHMOT			
TEST 3	0.005	38.77	AGE	0.362	-1.79	GPA SEX
	0.019	37.13	SATV	0.364	-0.15	GPA SEX SATQ
	0.033	35.45	SEX	0.369	1.31	GPA SEX SATQ SATV
	0.088	28.81	TOLT			
	0.125	24.39	SATQ			
	0.347	-2.03	GPA			
	0.000	50.72	SATV			
	0.000	50.69	SEX			
Composite*	0.001	50.67	ACHMOT	0.374	1.62	GPA SATV
Total	0.014	48.93	LOCUS	0.394	0.86	GPA SATV AGE
	0.015	48.74	AGE	0.403	1.67	GPA SATV AGE LOCUS
	0.059	42.61	TOLT			
	0.089	38.68	SATQ			
	0.350	2.90	GPA			

* Test1 + Test 2 + Test 3

Table 3

SUMMARY OF RESULTS SHOWING BEST SINGLE AND TWO VARIABLE MODELS*

QUARTER	TEST	GPA	SATQ	SATV	TOLT	LOCUS	SEX	AGE	ACHMOT	R^2(2 vars.)
SUMMER 1979 N= 100	1	.13	.42	.15	.39	.03	.00	X	X	.51
	2	.07	.30	.02	.14	.00	.02	X	X	.36
	3	.08	.48	.07	.39	.01	.00	X	X	.52
	4	.10	.24	.07	.10	.04	.01	X	X	.30
WINTER 1980 N= 525	1	.30	.14	.05	.05	X	.00	.00	X	.33
	2	.36	.16	.07	.06	X	.01	.01	X	.39
	3	.29	.18	.05	.08	X	.00	.00	X	.35
	4	.34	.12	.03	.05	X	.00	.00	X	.36
	5	.25	.07	.06	.04	X	.00	.00	X	.26
SPRING 1980 N= 280	1	.22	.16	.01	.06	X	.01	.01	X	.29
	2	.22	.16	.05	.09	X	.02	.01	X	.29
	3	.27	.12	.05	.08	X	.00	.01	X	.31
	4	.26	.06	.00	.03	X	.00	.00	X	.28
	5	.28	.15	.06	.05	X	.03	.00	X	.31
SUMMER 1980 N= 100	1	.42	.15	.02	.09	.00	.01	.00	.01	.31
	2	.38	.12	.01	.10	.00	.02	.00	.00	.39
	3	.35	.13	.02	.09	.00	.03	.00	.00	.36
	4	.35	.09	.00	.06	.01	.00	.02	.01	.37

*Variables in best two variable model are underlined.

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